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Role of olive oil phenolics in physical properties and stability of mayonnaise-like emulsions

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ABSTRACT

The effect of olive oil phenolic content and pattern on the physical properties and stability of olive oil mayonnaise-like emulsions has been investigated. Mayonnaises were formulated with either naturally phenolic-rich extra virgin olive oils or purified olive oil artificially enriched with a phenolic-rich olive extract and pure oleuropein. Mayonnaises were characterized by droplet size distribution, microstructure, textural properties and flow behaviour. The addition of phenolic extracts significantly affected the dispersion degree of the corresponding mayonnaise-like emulsions, their microstructure and physical stability especially in the systems prepared with purified olive oil treated with pure oleuropein and the highest olive phenolic extract concentration. The viscosity and back-extrusion analyses evidenced that the systems characterized by a relatively high content of phenolics, either natural or by addition, presented lower yield stress and viscosity indices and were easier to deform and to break. This study confirms the main role of olive phenolic compounds, and in particular that of oleuropein, in the dispersion state, and physical properties of emulsions with main effects on their quality and stability.

1. Introduction

Emulsion-based products are metastable systems which are highly susceptible to physical destabilization if not properly formulated and processed. Factors of various nature affect their role during storage as destabilizing mechanisms and phenomena may depend on chemical, physicochemical, physical and structural properties. As regards the latter, whilst important for the systems stability, they are also main determinants of consumer appreciation of the emulsified food products as they contribute to sensory and qualitative properties, such as creaminess, aroma and flavour perception (McClements, 1999).

Since the physical and structural characteristics of an oil-in-water (o/w) emulsion are strictly related to the dispersed oil phase, its nature and concentration, the phase volume of the dispersed droplets, the particle distribution, the interaction between oil droplets and the presence of other ingredients and food components that may influence the physical properties of the aqueous phase (e.g. thickening agents,...), it is clear that any alteration in one or more of these factors leads to different rheological, textural and sensorial properties.

In recent years, more attention has been paid to novel emulsified foods in terms of oil phase content but also in terms of alternative lipid sources (Jimenez-Colmenero, Herrero, Pintado, Solas, & Ruiz-Capillas, 2010; Lòpez-Lòpez, Cofrades, Yakan, Solas, & Jimenez-Colmenero, 2010; Matsakidou, Blekas, & Paraskevopoulou, 2010). In this respect, olive oil has received particular attention due to its beneficial effect on health. It is an important source of monounsaturated fatty acids, among which, oleic acid accounts for about 70–80% of the total and it is also rich in minor compounds and in particular in antioxidants, such as polyphenols (Cicerale, Lucas, & Keast, 2010; Frankel, 2010; Tripoli et al., 2005).

Olive oil polyphenols are a complex mixture of compounds with different chemical structures obtained from the oil's extraction procedure. Phenolic compounds are normally related to the oil oxidative stability and shelf life (Boskou, Tsimidou, & Blekas, 2006), but also to its sensory aspects and biological properties, as they are partially responsible for health benefits associated with the Mediterranean diet (Cicerale et al., 2010; Frankel, 2010; Tripoli et al., 2005). In recent years, attention has been focused on the technological aspects of olive polyphenolic compounds in emulsified food matrices: polyphenolic compounds with an amphiphilic structure, such as oleuropein, were indeed shown to exert some surface activity and influence the emulsification process in both model systems (Di Mattia, Sacchetti, & Pittia, 2011;

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Di Mattia et al., 2014; Souilem, Kobayashi, Neves, Jlaiel et al., 2014; Souilem, Kobayashi, Neves, Sayadi et al., 2014) and real complex formulations (Di Mattia et al., 2015). In particular, in the latter work, the authors noticed that when extra virgin olive oils were used in mayonnaise formulations, the dispersion degree and physical properties of the mayonnaise samples were deeply affected and the degree of destabilization was ascribed, among other factors, to the concentration of polyphenols of the oils (Di Mattia et al., 2015). However, since phenolic compounds can differ considerably in surface activity, their total content could not be the sole parameter governing extra virgin olive oil behaviour in multiphasic systems. Other factors, such as the phenolic pattern, may represent a critical issue worthy of investigation.

The aim of the present work was to study the effect of olive oil phenolic content and pattern on the physical properties and stability of a real emulsified complex system. To this end, mayonnaise-like systems were made according to a standardized procedure and recipe with two different approaches: (i) by using extra virgin olive oils (EVOO) naturally rich in phenolic compounds at two concentrations (low phenolic content, high phenolic content); (ii) by using purified olive oil that was artificially enriched with either a phenolic-rich olive pulp extract (at two different concentrations) or pure oleuropein. As reference, samples made of sunflower oil were also prepared.

To deepen understanding of the qualitative properties and stability of the mayonnaises differently produced, a preliminary chemical and technological characterization of the oils was carried out.

2. Materials and methods

2.1. Materials

The EVOOs were purchased from a local olive grower; the HP-EVOO (high phenolic) was made from Coratina olives whilst the LP-EVOO (low phenolic) was obtained from a blend of Leccino and Gentile di Chieti olives. The purified oil (PO) was obtained from LP-EVOO by following the purification procedure described by Paradiso, Gomes, Nasti, and Caponio (2010). Sunflower oil was purchased from the local market and used in the formulation of mayonnaise taken as control.

The olive pulp phenolic extract used in the study was kindly provided by Indena (Milano). Oleuropein was purchased from Extrasynthese (Lione, France). Fresh hen's eggs were purchased from a local supermarket; all the other reagents were of analytical grade and obtained from Sigma-Aldrich Ltd. (Steinheim, Germany).

2.2. Mayonnaise preparation

Concentrated mayonnaise-like systems were prepared in 500 g batches. For their production, a standardized mayonnaise recipe was used throughout the study, based on the following formulation (% on weight basis): 80% oil, 7.5% fresh egg yolk, 3.5% of a 10% acetic acid solution, 7.5% distilled water, 1% NaCl, 0.5% sucrose.

Artificially enriched mayonnaises were formulated and prepared by adding either a commercial phenolic olive extract at two different concentrations (0.1 and 0.2% w/w) or pure oleuropein (85 mg/kg). Concentrations of both phenolic extract and oleuropein were both set on oil phase weight. The concentrations of both the phenolic extract and of the oleuropein to be added to the systems were defined according to their natural presence in EVOOs.

Mayonnaise samples were prepared using a lab-scale mixer (Bimby TM31, Vorwerk, Wuppertal, Germany) in a two-step standardized process: eggs, vinegar and salt were preliminarily mixed (1st step – 100 rpm, 3 min) and then oil was slowly added under progressively increasing vigorous agitation (2nd step, from 3200 rpm to 6000 rpm, total time: 8 min).

The enrichments of the purified oil-based systems with either olive pulp phenolic extract or pure oleuropein were achieved by allowing the solubilization of the phenolic compounds during the first step of the homogenization procedure.

Samples were analyzed after preparation and after a storage of two weeks at 10 °C under dark conditions. For the latter, samples were poured into sterile glassy containers and hermetically closed with a metallic capsule.

2.3. Quality indices and composition of the oils and of the phenolic extract

Free fatty acids, peroxide and ΔK value of oils were determined according to the official methods defined by EC Regulation 2568/91 and subsequent amendments.

To characterize the phenolic pattern of both the oils and the extract, the phenolic fraction was preliminarily extracted by following the method by Pirisi, Cabras, Falqui Cao, Migliorini, and Muggelli (2000). This extract was thus used to determine both the total phenolic content by the Folin-Ciocalteau method (Singleton & Rossi, 1965) and the phenolic pattern by HPLC, according to Pirisi et al. (2000).

Quantification of α-tocopherol was carried out by HPLC analysis in agreement with the procedure proposed by Gama, Casal, Oliveira, and Ferreira (2000).

2.4. Interfacial tension

The oil/water interfacial tension (O/W) was measured with a tensiometer Attension Sigma 700/701 (Biolin Scientific Oy, Espoo, Finland) equipped with a Du Nouy platinum ring (diameter: 120.39 mm). Interfacial tension measurements were conducted after 30 min of equilibration time. Acetate buffer (pH 4.5, 50 mM) was used as aqueous phase.

2.5. Emulsifying properties

The oil capacity to be dispersed in an oil-in-water emulsion was determined by measuring the particle size of o/w emulsions prepared with 20% (w/w) of oil phase, 50 mM acetate buffer (pH 4.5) as continuous phase and Tween 20 as emulsifier (2,5% w/v). The emulsions were at first pre-emulsified at 12,000 rpm by a rotor-stator device (Ultra-Turrax yellow line DI25 basic) and then homogenized by a high pressure homogenizer (Panda Plus 2000, GEA Niro Soavi, Parma) with 5 cycles at a pressure of 150 Bar. Particle size measurements of fat globules of the emulsion were measured by a laser diffraction granulometer Mastersizer Hydro 3000 (Malvern Instrument, Malvern Worcestershire United Kingdom).

2.6. Particle size measurement

Particle size distribution was measured by a particle size analyser (Mastersizer 3000, Malvern Instruments Ldt, Worcestshire, UK) after following the conditions described by Liu, Xu, and Guo (2007).

2.7. Textural properties

Firmness and consistency of samples were evaluated with a back extrusion test by using a Dynamometer Instron Mod. 5542 (Instron Universal Testing machine, Royal Street Canton Ma, USA) equipped with a 35 mm-diameter probe. Mayonnaise samples (temperature: 25 °C) were placed in a glassy cell (inner diameter: